Modern Biology
Computerized Laboratories

Cellular Respiration

Apple® Version

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MODERN BIOLOGY
Computerized Laboratories

CELLULAR RESPIRATION

Teacher's Manual

Holt, Rinehart and Winston

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Cellular Respiration
Teacher's Manual

HOLT, RINEHART AND WINSTON

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Section 1

Introduction

The *MODERN BIOLOGY* Computerized Laboratories software series combines computer simulations of biological experiments with selected tutorials to enrich and expand students' understanding of concepts learned in the *Modern Biology* textbook. The *Cellular Respiration* program presents four experiments designed to foster progressively deeper insight into the process of cellular respiration. These simulations replicate as closely as possible the logic of actual laboratory experiments. They lead students to apply the scientific method: to observe, question, experiment, record, analyze, and interpret results. In addition, highly graphic, interactive tutorials support the simulations. The tutorials provide motivating content review.

Your *Modern Biology: Cellular Respiration* package includes:

- One double-sided program disk
- One Teacher's Manual with 8 reproducible Laboratory Worksheet masters

To use this program in your classroom you will need:

- An Apple IIe, IIc or IIGS computer, 128K required
- A video monitor or TV (color is preferable but not required)

This Teacher's Manual explains how to use the *Modern Biology* software, describes the contents of the *Cellular Respiration* disk, and provides strategies for using the software in the classroom.

Section 2

Making a Backup

It is always to your benefit to make a copy of your important disks in case of accidental loss or damage. **Make copies of the *Modern Biology* Disk for every day use and store the original disk for safekeeping.** Use either of the following copy methods.

> Note
>
> Before copying your software, place a write-protect tab (the small adhesive stickers are included with the purchase of blank diskettes) over the squared cutout on the original *Modern Biology* Disk.

Copying Disks with a DOS 3.3 System Master

You need two single-sided blank disks to copy the original disk. Label one disk Side 1 and the other disk Side 2.

1. Turn off the computer. Insert the DOS 3.3 System Master disk in Drive 1. Turn on the computer.
2. Press the CAPS LOCK key in the down position.
3. When the red "In Use" light on the disk goes out and you see a blinking cursor on the screen, type RUN COPYA. Press RETURN.
4. When the red "In Use" light on the disk goes out, remove the DOS 3.3 System Master disk.
5. Insert the original *Modern Biology* Disk in Drive 1 (with Side 1 facing

up) and the blank disk in Drive 2 (with Side 1 facing up). Be sure there is no write-protect tab on the blank disk. Press RETURN.

6. You are then prompted for the original slot and drive numbers. Enter **6** as the slot number and **1** as the drive number. Press RETURN after you enter both numbers. Next you are prompted for the duplicate slot and drive numbers. Enter **6** as the slot number and **2** as the drive number. Press RETURN after you enter both numbers.
7. The copy process then begins. When it is complete, the question **Do you wish to make another copy?** appears on the screen. Enter **Y** in response to the question. Press RETURN. Remove both disks.
8. Insert the original *Modern Biology* Disk (with Side 2 facing up) in Drive 1 and the target disk (with Side 2 facing up) in Drive 2.
9. Follow step 6. When you are finished copying disks, enter **N** in response to **Do you wish to make another copy?** Press RETURN.

Copying Disks with a ProDOS Master

You need two single-sided blank disks to copy the original disk. Label one disk Side 1 and the other disk Side 2.

1. Turn off the computer. Insert the ProDOS Master disk in Drive 1. Turn on the computer. The ProDOS User's Disk Main Menu appears.
2. Press **F** to select the **ProDOS FILER (UTILITIES)** option. The Filer Menu then appears.
3. Press **V** to select the **VOLUME COMMANDS** option. The Volume Commands Menu then appears.
4. Press **C** to select the **COPY A VOLUME** option. The Copy A Volume Menu then appears.
5. Remove the ProDOS Master disk.
6. You are then prompted for the slot and drive numbers. Enter **6** as the source slot number and **1** as the source drive number. The cursor automatically moves to the next line on the screen. Enter **6** as the target slot number and **2** as the target drive number. The message, **INSERT DISKS AND PRESS <RET>,** then appears at the bottom of the screen.
7. Insert the original *Modern Biology* Disk in Drive 1 (with Side 1 facing up) and the blank target disk in Drive 2 (with Side 1 facing up). Be sure there is no write-protect tab on the blank disk. Press RETURN.
8. Enter the name you want to give the target volume (no more than 15 characters) then press RETURN.
   If the target disk is not blank, you are asked to confirm that you want to destroy the information that is saved on the disk. Enter **Y** to continue copying.
   When the message **COPY COMPLETE** appears near the bottom of the screen, press RETURN and remove both disks.
9. Repeat step 6.
10. Insert the original disk (with Side 2 facing up) in Drive 1 and the target disk (with Side 2 facing up) in Drive 2.
11. Repeat step 8. When you are finished, turn off the computer.

Section 3

Loading Modern Biology: Cellular Respiration

To load your software:

1. Hold the disk by the label and insert Side 1 into the disk drive. Close the disk drive door. If you have two disk drives, use Drive 1.
2. Turn on the computer and the monitor or television set.

3. You will hear whirring noises as the program loads. After the title screen appears, follow the instructions on the screen.

Section 4

Teaching with Modern Biology: Cellular Respiration

Modern Biology: Cellular Respiration gives you a powerful set of tools with which to augment your teaching of *Modern Biology*. The software has two primary goals:

- To reinforce students' knowledge of both cellular respiration and the scientific method through laboratory simulations of experiments that are difficult or impossible to perform in the high school biology lab
- To use the graphics, interaction, and animation capabilities of the computer to present concepts that are difficult to teach with conventional methods.

The five units of the program are: The Energy of Respiration, Review of Cellular Respiration, Glycolysis, The Krebs Cycle, and The Electron Transport Chain. They can be used sequentially or independently of one another. Each lab and theory module is carefully structured to require little or no teacher support, and, further, to take no more than 20 to 30 minutes to complete.

To benefit most from the *Cellular Respiration* software, your students should already be familiar with the following concepts:

- Scientific method
- Characteristics of living things
- The nature of energy

Modern Biology: Cellular Respiration covers the following content:

1. The Energy of Respiration

Theory: The Energy of Respiration

This introductory theory module reviews the conversion of glucose energy into the energy of ATP. It covers the molecular structures of glucose, ADP, and ATP.

2. Review of Cellular Respiration

A. Lab: Pathways of Cellular Respiration

Students compare lactic acid production in two human subjects—one fit and one unfit—exercising for various lengths of time. In so doing, they gain insight into how humans shift between aerobic and anaerobic respiration to meet their energy needs.

B. Theory: Review of Cellular Respiration

The theory module defines cellular respiration, then uses a zoom sequence to introduce the mitochondrion and its parts. The tutorial also contrasts aerobic and anaerobic respiration and provides an overview of the steps involved in each.

3. Glycolysis

A. Lab: Anaerobic Respiration in Yeast

Students analyze the ability of yeast to metabolize a variety of sugars and sugar substitutes anaerobically. They use a manometer to measure CO_2 production and thus determine whether or not a given sugar has been metabolized.

B. Theory: Review of Glycolysis

This tutorial introduces glycolysis as the first step of cellular respiration, then guides the student through the step-by-step transformation of one molecule of glucose into two molecules of pyruvic acid. An "ATP Scoreboard" clearly indicates how much ATP is used and produced during glycolysis. The tutorial also reviews the chemical equation for glycolysis.

4. The Krebs Cycle

A. Lab: Aerobic Respiration

This lab challenges students to test the effects of different energy needs on the rate of aerobic respiration in a white rat and a white mouse. In the process, students learn that oxygen consumption is a reliable measure of rate of aerobic respiration.

B. Theory: Review of the Krebs Cycle

The tutorial provides an overview of the Krebs Cycle, focusing on the cycle's important function of contributing hydrogen and electrons to the Electron Transport Chain. An optional, step-by-step discussion of the cycle provides enrichment for advanced students.

5. The Electron Transport Chain

A. Lab: Electron Transport

Students add various poisons or antibiotics to a solution of succinate and mitochondrial fraction, then measure the absorbance of free phosphate to determine whether or not the Electron Transport Chain is working.

B. Theory: Review of the Electron Transport Chain

The tutorial uses an animation of the Electron Transport Chain to review the steps in electron transport, to demonstrate the importance of oxygen, and to illustrate how the majority of the cell's ATP is formed. The chemiosmotic theory is presented.

Section 5

Using Modern Biology: Cellular Respiration

Special Keys

Modern Biology software uses clear, on-screen prompts throughout to guide the user. There is, however, one special key that does not appear on screen: ESC.

The ESC key will take the user back to the previous menu. The user who presses ESC when in the middle of a tutorial or lab will return to the submenu. Pressing ESC from a submenu will return the user to the main menu. If the user has come to a tutorial from a lab rather than from a menu (this feature is described in greater detail later in this manual, under laboratory help options), ESC will return the user to the lab.

The Main Menu

The Main Menu for *Modern Biology: Cellular Respiration* offers the following choices:

1. The Energy of Respiration
2. Review of Cellular Respiration
3. Glycolysis
4. The Krebs Cycle
5. The Electron Transport Chain

Use the ↑ (up) and ↓ (down) arrow keys to highlight the unit you want, then press RETURN to select. You will use this basic menu selection technique throughout the program.

Once you have selected a unit to study, you will have a choice of going directly to the laboratory simulation or viewing the tutorial. The following is a description of interactions necessary to use these modules.

Laboratory Simulations

Each laboratory simulation is divided into three major sections: protocol, laboratory, and conclusions.

Protocol: The protocol screens introduce the experiment, let you select a hypothesis to test, and review the procedure for running the experiment. Clear, on-screen prompts guide the student through this part of the simulation. No special instructions are necessary.

Laboratory: The lab screens are divided into three parts. A command menu that runs across the top of the screen lets you set up and run an experiment, exit from the experiment, or receive help. To select an option from the command menu, use the ← (left) and → (right) arrow keys and RETURN. A text area at the bottom part of the screen provides instructions, prompts, and feedback. The central part of the screen contains the lab set-up on the left and a note pad on the right. The note pad contains a clock, temperature and light gauges as necessary, plus a space for recording results.

If you select ? (Help) from the command menu, you have three options:

- Commands: explains the command menu.
- Procedure: reviews the procedure for running the experiment.
- Theory: takes you to the content tutorial. You can move from the lab to the tutorial and back again at any time, except while an experiment is actually running or while tutorial questions are being asked. You will always return to where you left off in the lab. *To return from the tutorial to the lab, press ESC.*

Conclusions: Each lab concludes with questions that encourage students to interpret their experimental results and determine whether or not their hypothesis is correct. The program provides immediate feedback to both correct and incorrect responses.

Tutorials

The theory modules are highly graphic and interactive. They use two central approaches in presenting material, one for presenting structures such as the mitochondrion; the other for presenting processes such as electron transport. Structures are presented through a student-controlled "zoom" sequence that moves through increasingly detailed studies of the structure. Processes are presented through student-controlled animation sequences. As the student presses a key, the computer simulates the next step of the process under study. In addition to the zoom and animation routines, the theory modules incorporate interactive questions with immediate feedback to help students integrate the material they are learning. Except where specifically instructed, students use two basic keys to move through the tutorials:

→ moves forward a screen
← moves back one or more screens

Some questions in the tutorials require students to enter a number. In all of these cases, the computer will accept numbers only within a certain range. If the student tries to enter a number out of range (or a character other than a number), the computer will beep. If this happens, press the back arrow key to erase the entry and try again. Most often, the range of acceptable numbers reflects the range of legitimate answers to the question asked. The highest number the computer will ever accept is 10000.

Uses in the Classroom

Modern Biology: Cellular Respiration is carefully designed to provide maximum flexibility for classroom use. Both the labs and tutorials are appropriate for:

- **Individual Student Work**

The tutorials provide an excellent introduction to or review of concepts underlying the labs. Because students can move both forward and backward through the tutorials (and back and forth from a lab to a tutorial), they can master the material at their own pace. The labs also provide excellent opportunities for self-paced, individualized learning.

- **Cooperative Learning**

The labs can stimulate interesting group work and discussion. Three students working together, for example, could each select a different hypothesis to test, record experimental results, then discuss these results relative to the different hypotheses before answering the laboratory's concluding questions.

- **Whole Class Presentations**

You can use both the labs and the tutorials for classroom demonstrations. The modular presentation of the tutorial material makes it easy to find specific sections (an animated review of glycolysis, for example) that can reinforce your classroom teaching.

How to Use the Laboratory Worksheets

Reproduce enough copies of the Laboratory Worksheets to give one to each student who will use the *Modern Biology* simulations. Hand out the appropriate worksheets before students begin the lab. Have students fill in Part I of the worksheet as they review the Protocol section of the lab. As students run the lab, they should record their results in Part II of the worksheet. If you anticipate that students will run the experiment more than once, provide additional copies of the worksheets so that they can record data for each experiment.

Encourage students to fill in Part III of the worksheet before they answer the concluding questions in the laboratory simulation. In this way, they can double-check their own reasoning against the simulation's concluding questions.

You can use Part IV of the worksheets as enrichments or as quizzes to conclude your teaching unit on the process of cellular respiration.

Section 6

Laboratory Enrichments with Worksheets

The Energy of Respiration

Theory: Review of The Energy of Respiration

Objectives:

- To list a variety of activities that require energy.
- To explain how plants capture solar energy during photosynthesis and transform it into chemical energy.
- To explain that chemical energy can be released as glucose is broken into

CO_2 and H_2O.
- To describe the role of enzymes in the breakdown of glucose.
- To recognize the structural formulas of glucose and ATP.
- To describe the crucial role of ATP in energy-dependent activities.

Teaching ideas:

Students need to understand the nature of energy in order to understand how organisms use it. Introduce students to the Laws of Thermodynamics. They should understand that organisms do not create energy: they transform it. Stress that some of the energy stored chemical bonds is lost with each chemical reaction that takes place.

Explain to students that a calorie is the energy required to raise the temperature of one gram of water one degree Celcius. A calorie is a unit of energy equal to a kilocalorie and is used to describe the energy contained in foods.

Enrichments:

Students are curious about the calorie content of foods and what activities burn the most calories. An advanced student can explore the energy content of common foods. He or she can investigate how protein, carbohydrate, and fats differ in energy content and in how they are used by the body.

References:

Stryer, L. *Biochemistry, Second Edition.* San Francisco: W. H. Freeman and Co., 1981: 235-242.

Wallace, R. A., J. L. King, and G. P. Sanders. *Biology: the Science of Life.* Glenview, IL: Scott, Foresman and Co., 1986: 124-136.

Cellular Respiration

Theory: Review of Cellular Respiration

Objectives:

- To describe and relate the cellular locations of glycolysis, the Krebs cycle, and the Electron Transport Chain.
- To explain the molecular relationship between glycolysis, the Krebs cycle, and the Electron Transport Chain.
- To distinguish between aerobic and anaerobic respiration with respect to oxygen use and efficiency.
- To contrast anaerobic respiration as it occurs in yeast cells and in human muscle cells.

Teaching ideas:

Respiration is an abstract and difficult idea for most students. This concept becomes more accessible if presented as the means by which organisms extract energy and make it available to fuel the work of staying alive. Growth is a highly visible result of respiration that can be studied in the classroom. Have students combine baker's yeast, water, and table sugar. Then study the yeast cells under a microscope. Students can take rough population counts over time to monitor growth. At the same time, they will become familiar with the organism and will see evidence of respiration as bubbles form in the yeast suspension.

Enrichments:

The role of yeast and other microorganisms can be inspiring if considered on a global level. These organisms contribute to the decay of detrital material and to the release of important substances such as CO_2, which can be used by other members of the ecosystem. Students can research and construct food chains and webs showing how respiration—both aerobic and anaerobic—releases substances that are acted upon by other organisms. Students will recognize that microorganisms are vital members of the biosphere.

References:

Arms, K., and P. S. Camp, *Biology—Third Edition.* Philadelphia: Saunders College Publishing, 1987: 124-127.

Kendrick, B. *The Fifth Kingdom.* Waterloo, Ontario: Mycoloque Publications, 1985: 103-107; 277-281.

Margulis, L., and K. V. Schwartz. *Five Kingdoms: An Illustrated Guide to the Phyla of Life on Earth.* San Francisco: W. H. Freeman and Co., 1982: 150-151

Lab: Pathways of Cellular Respiration

Objectives:

- To compare the blood lactic acid values of a fit and an unfit individual as they exercise.
- To translate absorbance values into blood lactic acid values using a standard reference.

Teaching ideas:

Students can measure many physiological parameters at rest, during, and after exercise. Heart rate, pulse, blood pressure, and tidal volume are examples. The intimate relationship between the cardiovascular system, the respiratory system, and the demands of working muscles can be established this way. The demand for oxygen increases the activity of both the respiratory and cardiovascular systems. Remind students that although aerobic respiration makes large supplies of ATP available, the cardiovascular and respiratory systems cannot always meet the full demand for ATP. This is where anaerobic respiration comes into play. By converting pyruvic acid to lactic acid, muscle cells keep glycolysis going at a rapid rate, thus producing more ATP. This laboratory simulation provides meaningful insight into the shift from aerobic to anaerobic respiration.

This simulation also provides a good opportunity to introduce or reinforce the concept of homeostasis. Especially interesting is the drop in the lactic acid level as the untrained subject continues to exercise.

Enrichments:

A topic that will enrich students' understanding of anaerobic respiration, and respiration in general, is the importance of hydrogen acceptors such as NAD+. Ask students to go through the review of glycolysis—but have them pay particular attention to the role of NAD+. Ask them to form hypotheses about glycolysis when NAD+ level is low.

The assay simulated in this lab is an enzymatic assay: lactate dehydrogenase catalyzes the conversion of lactic acid (in blood plasma) to pyruvic acid. In the

process, NAD+ is reduced to $NADH_2$. The $NADH_2$ absorbs light at 340 nm, which can be measured with a spectrophotometer. Enzyme assays are standard for detecting many substances. An interested student could research the topic of enzymatic assay and justify its use in this type of experiment.

References:

G. A. Brooks and T. D. Faney. *Exercise Physiology: Human Bioenergetics and Its Applications.* New York: John Wiley and Sons, 1984: 189-198.

J. M. Clark and R. L. Switzer. *Experimental Biochemistry, Second Edition.* San Francisco: W. H. Freeman and Co., 1977: 256-257.

N. W. Tietz, Editor. *Textbook of Clinical Chemistry.* Philadelphia: W. B. Saunders Co., 1986: 816-818.

R. A. Walace, J. L. King, and G. P. Sanders. *Biology and the Science of Life, Second Edition.* Glenview, IL: Scott, Foresman and Co., 1986: 173-184.

Name _____ Date _____

LABORATORY WORKSHEET

Lab: Pathways of Cellular Respiration

I. What is the purpose of this experiment? _____

_____

What is your hypothesis? _____

_____

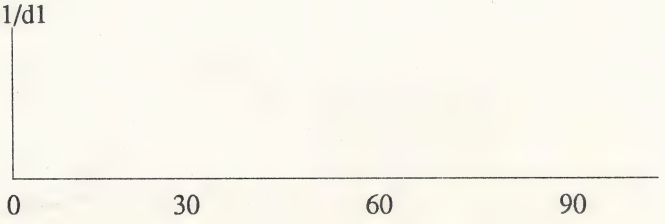
What do you predict will happen? _____

_____

II. Record your data in the table and graph below.

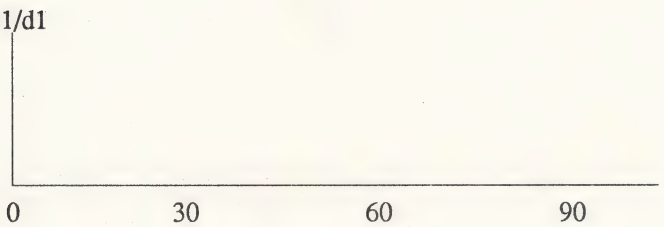
SUBJECT 1

Minutes	M1. Lactic Acid/dl blood



SUBJECT 2

Minutes	M1. Lactic Acid/dl blood



III. Do your data support your hypothesis? _____

What is your conclusion? _____

_____

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Lab: Pathways of Cellular Respiration

IV. Instructions: Answer the following questions on a separate sheet.

1. Write the overall equation for the conversion of pyruvic acid to lactic acid.

2. How many molecules of lactic acid are produced for each molecule of glucose metabolized?

3. The two human subjects in this lab are matched for age, sex, and weight. Why is this important?

4. Which subject showed the greatest change in lactic acid blood levels? Why do you think the level rose for this subject?

5. Why do you think aerobic exercise (jogging, swimming, etc.) is so called?

6. Why is the amount of exercise a person can do limited?

7. Why does a respiratory problem such as pneumonia severely restrict an individual's activities?

8. Red blood cells don't have nuclei or mitochondria. How do they produce ATP?

9. Blood levels of lactic acid can increase if a person has poor circulation. Why?

10. In this lab, you measured lactic acid levels in the blood. You could have measured oxygen consumption at the same time. Form a hypothesis about the results of an experiment that measured oxygen consumption.

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Theory: Review of Glycolysis

Objectives:

- To review the chemical equation that summarizes glycolysis.
- To explain the role of enzymes and ATP in glycolysis.
- To describe the possible fates of the $NADH_2$ that is formed during glycolysis.
- To explain what happens to pyruvic acid under aerobic and anaerobic conditions in yeast cells and in human muscle cells.

Teaching ideas:

You can demonstrate the breakdown of glucose into two molecules of pyruvic acid with the plastic molecular models often used in chemistry classes. Demonstrate the activating influence of ATP's contribution of energy and a phosphate group. At the end of the demonstration, display the products of glycolysis and discuss their fates.

Glycolysis is a process common to all eukaryotes. Therefore, it must be an ancient process. The process offers obvious advantages to those cells or organisms in which it is found. Stimulate your students to think about what is really being conserved in the course of evolution to make glycolysis common to so many organisms. Lead them to conclude that a group of genes that codes for the enzyme sequence in the glycolysis pathway has been conserved. Guide your students to the insight that apparently diverse organisms are very similar on a biochemical level.

Enrichments:

Fermentation results in a great variety of products. Have advanced students research the variety of anaerobic pathways that exist among microorganisms. Many of the products of fermentation, such as acetone and butanol, are of industrial value and are therefore produced commercially in great quantities.

References:

Cano, R. J., and J. S.Colome, *Microbiology*. St. Paul, MN: West Publishing Co., 1986: 186-190.

Stryer, L. *Biochemistry, Second Edition*. San Francisco: W. H. Freeman and Co., 1981: 255-270.

Wallace, R. A., J. L. King, and G. P. Sanders. *Biology: The Science of Life, Second Edition*. Glenview, IL: Scott, Foresman and Co. 1986: 173-184.

Lab: Anaerobic Respiration in Yeast

Objectives:

- To detect the presence of CO_2 as an indication of fermentation.
- To distinguish those substances that support fermentation from those that do not.

Teaching ideas:

You can approach the study of glycolysis by studying fermentation, which is essentially a slight extension of glycolysis. Make yogurt in the classroom for a simple and effective demonstration of fermentation. Inoculate cooled, scalded milk with a teaspoon of yogurt. The solution will develop into yogurt in 12-24 hours if kept above room temperature; it will take longer at lower temperatures. As time goes by, students can watch changes in pH as well as the concurrent changes in texture. The bacteria that make the yogurt are called lactic acid bacteria because they produce lactic acid rather than alcohol via fermentation. Discuss other food products, such as bread and alcoholic beverages, in which fermentation is also an important process.

Enrichments:

Advanced students can extend their understanding of anaerobic respiration in either the library or the field. Research into the work of Louis Pasteur is interesting from both an historical and a scientific perspective. His early experiments not only helped France's wine industry but also provided the first clues as to how metabolism works.

Out in the field, students can look for evidence of fermentation in the natural ecosystem. Students can discuss and plan experiments to prove that what they think may be evidence of fermentation in the wild (e.g., decaying leaves; sour smells) actually is.

References:

Cano, R. J. and J. S. Colome. *Microbiology.* St. Paul, MN: West Publishing Co., 1986: 186-194.

Godrick, E. *Principles of Biology II Laboratory Manual.* Lexington, MA: Ginn Publishing, 1984: 71-73.

Hauser, J. T. "Yeasts in the Classroom." *Carolina Tips* 48, no. 10 (1985): 37-39.

Name _____ Date _____

LABORATORY WORKSHEET

Lab: Anaerobic Respiration in Yeast

I. What is the purpose of this experiment?_____

_____

What is your hypothesis?_____

_____

What do you predict will happen?_____

_____

II. Record your data in the table below.

Sugar	M1 CO_2

III. Do your data support your hypothesis?_____

What is your conclusion?_____

_____

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Lab: Anaerobic Respiration in Yeast

IV. Instructions: Answer the following questions on a separate sheet.

1. In this experiment, you collect CO_2 as a measure of fermentation. However, CO_2 is also formed during aerobic respiration. What other product is produced that is unique to fermentation?

2. Which product of fermentation is important in bread making and where does it go?

3. The yeast cells capture the energy of some sugars. What form does this usable energy take?

4. How do you think the yeast cells use this energy?

5. In nature, yeast live on fruit, in soil, and in the nectar of flowers. Does this help explain why yeast can break down some sugars but not others?

6. How does glucose differ from ribose? From sucrose?

7. Some molecules taste sweet to people but do not yield the calories of sugar. How can this be?

8. Starter cultures that contain bacteria capable of fermentation are needed to make such dairy products as yogurt and sour cream. Why?

9. Many adults cannot drink fresh milk without getting sick, but they can tolerate fermented milk products such as yogurt. The active agent in yogurt is a bacteria that ferments lactose. Why do you think people can tolerate the fermented milk but not the fresh milk?

10. Tooth decay is caused by bacteria that produce acids that are destructive to teeth. Do you think that these bacteria form acids as a result of aerobic or anaerobic respiration? Defend your answer.

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The Krebs Cycle

Theory: Review of the Krebs Cycle

Objectives:

- To list the relationship between the Krebs cycle and glycolysis.
- To describe the Krebs cycle as a series of chemical transformations.
- To list the intermediate molecules and end products of the Krebs cycle.
- To explain the importance of NAD+ and FAD as electron acceptor molecules.

Teaching ideas:

When first teaching this material in class, use the program to provide an overview of the Krebs cycle. Emphasize the cyclical nature of the eight reactions and discuss the significance of the end products of the cycle. After the students understand the overall significance of the Krebs cycle, they can go back and look at each individual transformation in the cycle.

Enrichments:

Students might enjoy studying one of the following related topics:

- The research of Sir Hans Kreb who was awarded the Nobel Prize in 1953.
- The endosymbiotic hypothesis.
- The maternal inheritance of cellular respiratory disorders.

References:

Cano, R. J. and J. S. Colome. *Microbiology*. St. Paul, MN: West Publishing Co., 1986: 190-198.

Stryer, L. *Biochemistry, Second Edition*. San Francisco: W. H. Freeman and Co. 1981: 307-325.

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Lab: Aerobic Respiration

Objectives:

- To quantify the relationship between exercise and oxygen consumption.
- To compare oxygen consumption data of a mouse with that of a rat.

Teaching ideas:

The link between oxygen consumption and increased exercise is intuitive and can be used to introduce this lab. Students will probably predict that as the animal runs faster, it will consume more oxygen. This is of course true. The data generated in this lab will verify that hypothesis and show clearly how oxygen consumption can be measured. In addition, the experiment can lead students to discover additional information. The mouse and the rat are significantly different

in size. Discuss the effect this may have on oxygen consumption. These data may be surprising. Although the rat consumes more oxygen than the mouse, the mouse consumes more oxygen per unit of body weight. This provides an excellent opportunity to discuss the manipulation of data in trying to establish and clarify relationships.

Students should discuss the experimental design. They should realize that as oxygen is consumed, CO_2 is produced. This could invalidate the experimental results. However, in experiments of this kind, the CO_2 is absorbed so that it does not accumulate. A change in the manometer fluid level is therefore directly related to a change in the oxygen level in the air of the chamber. Another assumption you should acknowledge is temperature control. In this experiment, the temperature of the entire system is constant so any change in the manometer reading is due to a change in oxygen level, not in changes in gas volume due to temperature change.

Enrichments:

Both the white mouse and the white rat are warm-blooded mammals. Have students predict how the experimental results might differ if an amphibian or a reptile were to exercise in a similar way. Consider the design of an experiment to test these animals. Pay careful attention to the new variable that must be considered: temperature. Temperature changes greatly influence the activities of poikilotherms.

References:

Eckert, R., and D. Randall. *Animal Physiology: Mechanisms and Adaptation, Second Edition.* San Francisco: W. H. Freeman and Co., 1983: 697-705.

Schmidt-Nielsen, R. *Animal Physiology: Adaptation and Environment, Third Edition.* Cambridge, MA: Cambridge University Press, 1983: 201-213.

Name _____ Date _____

LABORATORY WORKSHEET

Lab: Aerobic Respiration

I. What is the purpose of this experiment? _____

_____

What is your hypothesis? _____

_____

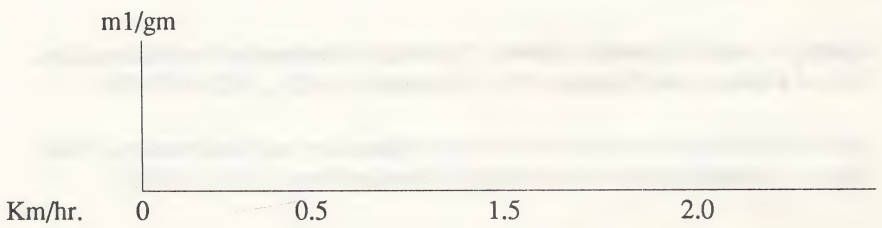
What do you predict will happen? _____

_____

II. Record your data in the table and graph below.

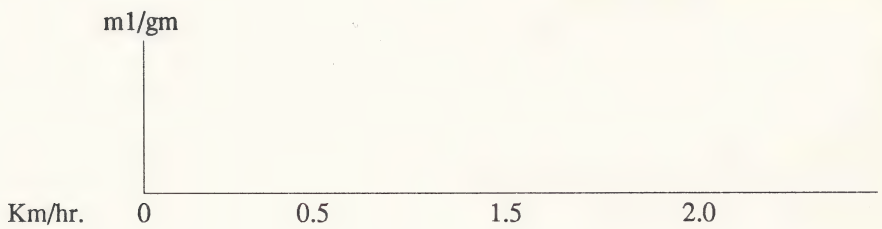
SUBJECT 1

Km/hr.	M1. O_2 /gram



SUBJECT 2

Km/hr.	M1. O_2 /gram



III. Do your data support your hypothesis? _____

What is your conclusion? _____

_____

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Lab: Aerobic Respiration

IV. Instructions: Answer the following questions on a separate sheet.

1. Which animal actually consumes more oxygen?

2. If you could measure how much oxygen one mouse cell used compared to one rat cell, how would they compare?

3. Do you think that these animals are producing some lactic acid as they run?

4. Do you think the volume of CO_2 exhaled increases or decreases during exercise? Why?

5. The laboratory set-up used here has a built-in trap that absorbs CO_2 produced by the animals. Why is this important?

6. Are the cells of the animal able to extract and use all of the energy in the glucose molecules?

7. Would increasing or decreasing the temperature at which these experiments are run by several degrees affect the amount of oxygen consumed?

8. Conduct a mental experiment: a frog and a mouse of equal weight are tested using the experimental apparatus. Do you think that they will consume equal amounts of oxygen? Why?

9. The computer calculated the volume of oxygen consumed per gram of tissue per hour from the raw data (oxygen consumed per minute). Replicate this calculation by following these steps:
   a. Your mouse consumed 2.0 ml of O_2 in a minute. How much did it consume in an hour?
   b. Divide the amount of O_2 consumed in an hour by the weight of the mouse (21 grams). Your answer gives you the amount of oxygen consumed per gram of body weight.

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The Electron Transport Chain

Theory: Review of the Electron Transport Chain

Objectives:

- To explain how the passage of electrons through the chain is coupled with the accumulation of H+ outside the mitochondrial membrane.
- To show how the accumulation of H+ outside the membrane and the ATP synthetase contribute to the formation of ATP and to define chemiosmotic hypothesis.
- To summarize the total number of ATP's formed at each stage of cellular respiration in aerobic organisms.

Teaching ideas:

The electron transport chain can be compared with a bucket brigade comprised of buckets of decreasing size. Each bucket holds less water and therefore has less potential energy. Some water (analogous to potential energy) is "lost" with each transferral, but the lost water has the potential to move something (analogous to moving H+ outside). Similarly, each member of the chain holds onto the electrons with less energy. This allows for the release of energy in small, controllable amounts. It is important to emphasize the cell's control of the process and the gradual release of energy as it is captured in the form of ATP. The diversion of electrons through the chain results in the formation of usable energy, ATP.

Enrichments:

Advanced students can reach a deeper understanding of the electron transport chain by studying how the process operates in bacteria. Bacteria are prokaryotes and therefore have no mitochondria. Some bacteria are thought to have given rise to mitochondria by endosymbiosis.

Advanced students can also explore the relationship between the electron transport chain and bioluminescence, or compare the electron transport chain as it occurs in the mitochondria with the ETC as it occurs in the light reaction of photosynthesis in chloroplasts.

References:

Alberts, B., et al. *Molecular Biology of the Cell.* New York: Garland Publishing Inc., 1983: 500-513.

Cano, R. J. and J. S. Colome. *Microbiology.* St. Paul, MN: West Publishing Co., 1986: 190-198.

Stryer, L. *Biochemistry, Second Edition.* San Francisco: W. H. Freeman and Co., 1981: 307-325.

Wallace, R. A., J. L. King, and G. P. Sanders. *Biology: The Science of Life, Second Edition.* Glenview, IL: Scott, Foresman and Co., 1986: 189-195.

Lab: The Electron Transport Chain

Objectives:

- To monitor the activity of the Electron Transport Chain by observing a change in absorbance as phosphate combines ADP to form ATP.
- To identify substances that inhibit the Electron Transport Chain.

Teaching ideas:

Students should be familiar with the Electron Transport Chain (ETC) before they run this simulation. They should also understand how it works in consort with both glycolysis and the Krebs cycle. Challenge students to think about how they might study the functioning of the chain. They might suggest that they monitor the disappearance of the substance that supplies electrons, or of the final acceptor, oxygen. These are two good ways of monitoring the ETC. Another way is to follow the disappearance of free phosphate as ATP is formed. This is the parameter measured in this simulation, using a spectrophotometer and a light source at 660 nm, which phosphate absorbs.

You may need to remind students that the ETC is what makes organisms aerobic, i.e., dependent upon oxygen for survival. Also remind them of the differences in the products of anaerobic and aerobic respiration. You can relate these concepts to one of our most important problems: sewage treatment. If we bubble air through the wastes, aerobic microorganisms (aerobes) will completely break down the organic material into CO_2 and O_2. If oxygen is limited, however, anaerobes ferment the material, producing a variety of products (e.g., alcohols, acids) that create foul smells and unclean water. Put in this context, the importance of a process that occurs on a molecular level to the quality of life on the community level—indeed, on the global level—becomes clear.

Enrichments:

Students many be interested in learning more about the spectrophotometer. They can research the architecture and functioning of a simple spectrophotometer and can sketch the relevant parts. They can also explain the use of blanks and standard curves in this type of work.

References:

Boyer, R. F. *Modern Experimental Biochemistry*. Reading, MA: Addison-Wesley Publishing Co., 1986: 489-498; 570.

Clark, J. M., and R. L. Switzer. *Experimental Biochemistry, Second Edition*. San Francisco: W. H. Freeman and Co., 1977: 265-273.

Lenninger, A. *Principles of Biochemistry*. New York: Worth Publishers, Inc., 1982: 467-505.

Name _____ Date _____

LABORATORY WORKSHEET

Lab: The Electron Transport Chain

I. What is the purpose of this experiment? _____

_____

What is your hypothesis? _____

_____

What do you predict will happen? _____

_____

II. Record your data in the table below.

Substance	Absorbance

III. Do your data support your hypothesis? _____

What is your conclusion? _____

_____

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Lab: Electron Transport Chain

IV. Instructions: Answer the following questions on a separate sheet.

1. Why is measuring the disappearance of phosphate a valid method for monitoring ATP production by the ETC?

2. Will ATP be formed in the usual amounts if the passage of electrons proceeds normally, but something is wrong with the enzyme ATP synthetase?

3. Why do the electrons carried into the ETC by $FADH_2$ as compared with NADH, support the formation of fewer ATP molecules?

4. Is the ETC the only way a cell can form ATP?

5. If cells can make ATP in other ways, why are poisons that affect the ETC so dangerous?

6. How does something that interferes with the delivery of oxygen to cells affect the ETC?

7. The terms oxidation and reduction are often used in describing how the ETC operates. Define these two terms.

8. Write a chemical equation that summarizes ATP formation.

9. What are the two products of the ETC?

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Section 7

Glossary

acceptor molecules: molecules that bind hydrogen or electrons released in chemical reactions and release them as needed.

acetyl-coenzyme A (acetyl coA): an important molecule produced from pyruvic acid, the end-product of glycolysis, that enters the Krebs cycle; the link between glycolysis and the Krebs cycle in aerobic organisms.

ADP (adenosine diphosphate) an energy storage molecule that contains one high-energy phosphate bond.

aerobe: an organism that requires oxygen for respiration: plants, animals, and some microogranisms are aerobes.

aerobic respiration: the series of reactions through which cells convert glucose into usable chemical energy in the presence of oxygen.

alcoholic fermentation: a form of anaerobic respiration during which glucose is broken down into ethyl alcohol, carbon dioxide, and ATP.

anaerobe: a microorganism that respires in the absence of oxygen.

anaerobic respiration: the series of reactions through which cells convert glucose into useable chemical energy in the absence of oxygen.

ATP (adenosine triphosphate): an energy storage molecule that contains two high-energy phosphate bonds: the source of usable energy in cells.

ATP synthetase: an important enzyme that catalyzes the formation of ATP.

calorie: the amount of heat needed to raise the temperature of one gram of water one degree celsius.

Calorie: a measure of the energy produced by food when oxidized in the body; 1000 calories.

cellular respiration: the breakdown of glucose to release energy essential for cellular maintenance and growth.

chemiosmotic theory: a theory that explains how the ETC functions in the formation of ATP.

christae: the inner membranes of mitochondria.

coenzymes: nonprotein molecules that act with enzymes in catalyzing reactions.

cytoplasm: the cell material between the nucleus and the cell membrane; location of many reactions, including glycolysis.

electron transport chain: a chain of molecules that act as electron carriers in the final stage of aerobic respiration and participate in the formation of ATP.

energy: the capacity to do work or cause change.

enzymes: proteins that control the release of energy in the cell; catalysts of chemical reactions that occur in cells.

FAD: an acceptor molecule.

glucose: a six-carbon molecule that is an end-product of photosynthesis; energy stored in the bonds of the glucose molecule is released during cellular respiration.

glycolysis: the first stage of cellular respiration; an anaerobic process during which glucose is broken down into pyruvic acid and some ATP and $NADH_2$ are formed.

Krebs cycle: the second stage of cellular respiration in aerobic organisms, during which electrons and hydrogen are made available for the final stage, the electron transport chain.

lactic acid fermentation: anaerobic respiration in humans, during which lactic acid and energy are produced.

matrix: the enzyme-rich, liquid contents of mitochondria.

mitochondria: rod-shaped organelles that are the centers of cellular respiration.

NAD+: an acceptor molecule.

nanometer (nm): a measure of the wavelength of light.

nucleus: a double-membrane organelle that encloses the cell's genetic material.

oxidation: the release of electrons by a donor to another molecule.

pyruvic acid: an end-product of glycolysis.

reduction: the addition of electrons and/or hydrogens to a molecule.

Answers to Worksheet Questions

Pathways of Cellular Respiration

1. Pyruvic acid + $NADH_2$ → lactic acid + NADH+.
2. The breakdown of glucose yields two molecules of pyruvic acid, and therefore two molecules of lactic acid.
3. In order to make valid comparisons, the two subjects should be as much alike as possible. The only variable is conditioning.
4. The unfit subject. The unfit subject switches to anaerobic respiration more quickly because his cardiovascular and respiratory systems are not as able to deliver oxygen to working muscles as are those of the fit subject.
5. It is called aerobic exercise because it increases the oxygen-delivering capacity of the body, thus delaying the switch to anaerobic respiration.
6. The glucose supply is limited. In addition, lactic acid builds up in muscles, causing fatigue.
7. Diseases of this type interfere with the delivery of oxygen to all parts of the body. ATP production is slowed.
8. Because they do not have mitochondria, red blood cells can respire only anaerobically. All of their ATP comes from glycolysis.
9. Slow circulation slows the delivery of oxygen to muscle cells, causing the cells to use anaerobic respiration more often.
10. Answers will vary, but should be something like: The fit subject will consume more oxygen than the unfit subject doing the same amount of exercise.

Anaerobic Respiration in Yeast

1. Alcohol.
2. CO_2 is important in bread making. It escapes and causes the bread to rise. The alcohol produced during fermentation evaporates.
3. ATP.
4. Some ATP is used to break down other sugar molecules; some is used to repair the cells; some to make proteins; some for reproduction, etc.
5. Yes. Yeast can ferment those sugars found in its natural environment.
6. Glucose is a six-carbon sugar; ribose is a five-carbon sugar; and sucrose is a 12-carbon sugar.
7. The enzyme that breaks down sugar may not be able to break down the other sweeteners. However, the taste buds that detect sweet tastes are equally stimulated by the sugar and the sugar substitutes.
8. Through fermentation these bacteria produce new substances, such as lactic acid, that change the taste and, sometimes, the texture, of the food.
9. The bacteria change lactose, the substance some adults cannot tolerate, into lactic acid, a substance they can tolerate.
10. They use anaerobic respiration, which produces the harmful acids. Aerobic respiration would produce harmless CO_2 and water.

Aerobic Respiration

1. The rat consumes more oxygen because it is larger.
2. Since the mouse consumed more on a per gram basis, it will most likely consume more on a per cell basis too.
3. Probably, but lactic acid is not being measured.
4. Since the rate of aerobic respiration increases, CO_2, which is a product of aerobic respiration, also increases.
5. Since CO_2 is a gas, it could replace the oxygen in the air that the animals consumed. The CO_2 must be trapped to assure an accurate measure of

oxygen consumption.

6. No. Some energy always escapes during chemical reactions.
7. Probably not. Warm-blooded animals maintain a fairly constant internal body temperature and would therefore consume the same amount of oxygen.
8. The mouse will probably consume more oxygen than the frog. Mammals have higher rates of metabolism and therefore use more oxygen.
9. a. $\frac{2\text{ml}}{\text{min}} \times \frac{60\text{ min}}{\text{hr}} = \frac{120\text{ml}}{\text{hr}}$

   b. $\frac{120\text{ml}}{\text{hr}} \div 21\text{g} = 5.7\ \frac{\text{ml}}{9.\text{hr}}$

Electron Transport Chain

1. Phosphate joins with ADP to form ATP, so for every ATP molecule formed, one phosphate molecule "disappears."
2. No. Both the ETC and the enzyme must be working properly.
3. The electrons get passed to an acceptor in the middle of the chain, not the beginning, so they skip one of the acceptors that transports H+. This means that fewer H+ flow through the membrane to support the formation of ATP.
4. No. Some ATP is formed during both glycolysis and the Krebs cycle.
5. The ETC produces much greater amounts of ATP than the other reactions do. If the ETC is blocked, the cells or organisms don't get enough ATP and therefore die.
6. Without enough oxygen to accept the electrons at the end of the chain, the passage of electrons is blocked.
7. Oxidation is the release of electrons by a donor. The molecule that receives the electrons is reduced at the same time.
8. ADP + phosphate + energy → ATP
9. Water and ATP.

TEACHER'S NOTES

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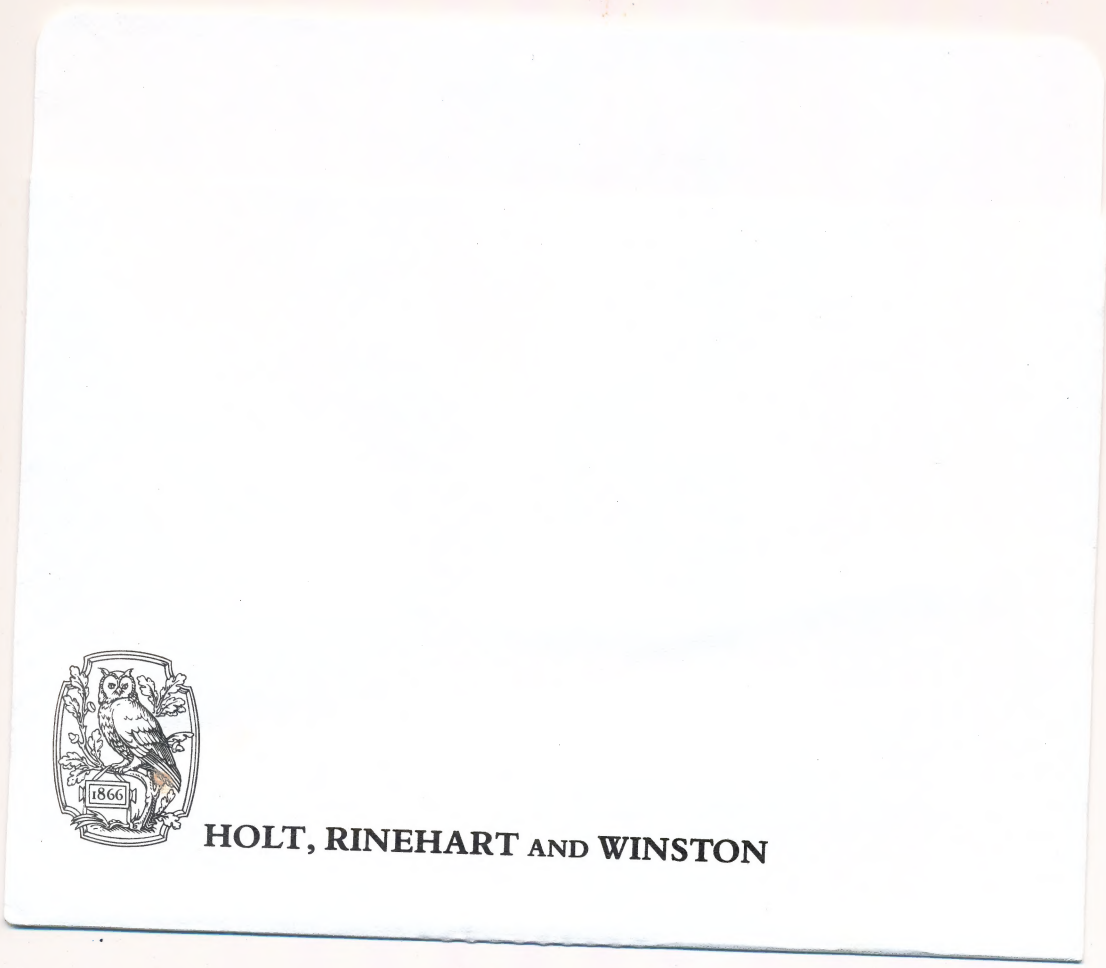
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MODERN BIOLOGY COMPUTERIZED LABORATORIES

Cellular Respiration

Side 2

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Schützen
保護

No
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Non
Nicht
注意

Insert carefully
Insertar con cuidado
Inserer avec soin
Vorsichtig Einführen
挿入注意

Never touch!
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Jamais toucher!
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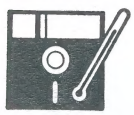

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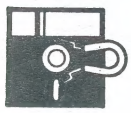
50°F → 125°F



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